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Lake Corpus Christi Jim Wells, Live Oak, and San Patricio Counties, Texas

National Eutrophication Survey, Corvallis, Oreg

Prepared for

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and quantified according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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Report
on
Lake Corpus Christi
Jim Wells, Live Oak,
and San Patricio Counties
Texas
EPA Region VI
Working Paper No. 641

With the cooperation of the
Texas Water Quality Board
and the
Texas National Guard
February, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass

LAKE CORPUS CHRISTI

STORET NO. 4811

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Corpus Christi is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, the Texas Water Quality Board has indicated that there is little or no known impairment of the designated beneficial uses of this lake.

Lake Corpus Christi ranked thirty-seventh in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*. Thirty-five of the reservoirs had less median total phosphorus and median dissolved orthophosphorus, 20 had less median inorganic nitrogen, 33 had less mean chlorophyll a, and 31 had greater mean Secchi disc transparency. Marked depression of dissolved oxygen with depth occurred at stations 1 and 4 in May and at station 1 in August.

Survey limnologists observed macrophytes in the shallows at stations 1, 2, and 4 in November but did not observe any surface algal concentrations.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Lake Corpus Christi was nitrogen limited at the time the sample was collected (03/12/74).

* See Appendix A.

The lake data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, the listed point sources contributed 4.1% of the total phosphorus load to Lake Corpus Christi. The wastewater treatment plant at Mathis contributed an estimated 2.2%, and two other facilities at George West and Three Rivers collectively contributed 1.8%.

The present phosphorus loading of 2.40 g/m^2/year is four times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 15). Regardless of the applicability of Vollenweider's eutrophic level to Texas reservoirs, control of phosphorus only at the listed point-sources would not be expected to result in appreciable improvement in the trophic condition of the lake. Significant reduction of the present phosphorus loading will require control of both point and non-point source contributions in the entire Lake Corpus Christi drainage basin (see discussion below).

2. Non-point sources--Non-point sources contributed 95.9% of the total phosphorus input during the sampling year. The Nueces River contributed 91.7%, and the ungaged minor tributaries and immediate drainage contributed an estimated 3.5%.

The phosphorus export rate of the Nueces River was 5 kg/km^2 during the sampling year and may be indicative of an underestimation of listed point-source loads, the presence of unaccounted-for point sources, or the influence of land-use practices in the drainage basin. However, even if the present Nueces River load could be

reduced by 70%, the relatively large drainage area to lake area ratio of 486 to 1 would still ensure a eutrophic loading to the lake; i.e., the loading would still be 0.86 g/m²/year, or 1.5 times Vollenweider's eutrophic loading.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 88.63 kilometers².

2. Mean depth: 4.2 meters.

3. Maximum depth: >15.8 meters.

4. Volume: 372,246 x 10^6 m^3.

5. Mean hydraulic retention time: 175 days (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Nueces River	41,569.	24,470
Minor tributaries & immediate drainage -	1,491.3	0.930
Totals	43,060.8	25,400

2. Outlet -

Alice Aqueduct		0.101
Nueces River	43,149.4**	24,470
Total	43,149.4	24,571

C. Precipitation***:

1. Year of sampling: 78.8 centimeters.

2. Mean annual: 73.4 centimeters.

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† Table of metric conversions--Appendix B.
†† Latchford, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Lake Corpus Christi was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at four stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 16.8 meters at station 1, 7.6 meters at stations 2 and 3, and 10.7 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table (the August nutrient samples were not preserved properly and were not analyzed).

A SURVEY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CHAMPLAIN CANAL AND STUMP CREEK MARSH

PARAMETER	1ST SAMPLING : 3/13/74 — 4 SITES			2ND SAMPLING : 5/22/74 — 4 SITES			3RD SAMPLING : 8/13/74 — 4 SITES		
	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	20.1 - 23.0	22.5	22.4	25.6 - 29.0	27.3	28.0	27.0 - 29.0	28.3	28.4
DISS OXY (MG/L)	5.0 - 8.2	7.4	7.6	1.0 - 8.0	5.6	6.0	1.0 - 8.2	5.8	6.2
CNDCTVY (MICRO)	558. - 1152.	752.	746.	746. - 3405.	1887.	887.	458. - 1835.	895.	885.
PH (STAND UNITS)	8.2 - 8.6	8.5	8.5	7.7 - 8.7	8.5	8.6	7.8 - 8.8	8.4	8.5
TOT ALK (MG/L)	170. - 181.	175.	175.	144. - 162.	154.	152.			
TOT P (MG/L)	0.081 - 0.110	0.095	0.095	0.072 - 0.251	0.124	0.107			
DFTHO P (MG/L)	0.039 - 0.054	0.046	0.047	0.022 - 0.237	0.052	0.040			
NO2+NO3 (MG/L)	0.033 - 0.338	0.072	0.040	0.078 - 0.325	0.119	0.095			
AMMONIA (MG/L)	0.035 - 0.089	0.040	0.040	0.033 - 0.398	0.088	0.060			
KJEL N (MG/L)	0.388 - 0.880	0.593	0.488	0.487 - 1.488	0.674	0.688			
NORG N (MG/L)	0.355 - 0.433	0.392	0.386	0.046 - 0.550	0.198	0.138			
TOTAL N (MG/L)	0.538 - 0.838	0.685	0.646	0.438 - 1.450	0.774	0.650			
CHLOPHYL A (UG/L)	7.6 - 17.3	11.1	9.6	6.6 - 38.6	22.6	22.7	4.6 - 77.5	35.6	25.9
SECCHI (METERS)	0.5 - 0.8	0.6	0.6	0.3 - 1.2	0.6	0.8	0.1 - 0.9	0.6	0.6

A SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CHAMPLAIN CANAL
STUDY CODE 4411

SAMPLING DEPTH

PARAMETER	RANGE	MEAN	MEDIAN
TEMP (C)	23.0 - 25.0	24.3	24.0
DISS OXY (MG/L)	5.0 - 8.0	7.0	7.0
CHEMICAL OXYGEN DEMAND	160.0 - 1250.0	325.0	230.0
PH (STAND UNITS)	7.0 - 8.0	8.2	8.2
TOT ALK (MG/L)	125.0 - 140.0	129.0	127.0
TOT P (MG/L)	0.140 - 1.380	0.227	0.170
DISS P (MG/L)	0.071 - 0.124	0.104	0.111
NO2+NO3 (MG/L)	0.040 - 0.270	0.127	0.120
AMMONIA (MG/L)	0.020 - 0.120	0.048	0.030
T.K.N. (MG/L)	0.280 - 2.700	0.581	0.480
NO2+NO3 (MG/L)	0.070 - 0.330	0.157	0.150
TOTAL N (MG/L)	0.310 - 2.400	0.784	0.620
CHLOPHYL A (MG/L)	11.5 - 25.0	16.4	15.0
SECCHI (METERS)	0.3 - 0.8	0.5	0.5

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/12/74	1. Merismopedia sp.	1,330
	2. Scenedesmus sp.	1,216
	3. Chroomonas sp.	874
	4. Kirchneriella sp.	874
	5. Microcystis sp.	836
	Other genera	5,209
	Total	10,339
05/21/74	1. Centric diatoms	1,451
	2. Diploneis sp.	747
	3. Scenedesmus sp.	484
	4. Merismopedia sp.	440
	5. Anabaena sp.	396
	Other genera	2,548
	Total	6,066
08/14/74	1. Diploneis sp.	766
	2. Dactylococcopsis sp.	468
	3. Lyngbya sp.	468
	4. Oscillatoria sp.	468
	5. Raphidiopsis sp.	383
	Other genera	2,512
	Total	5,065
11/05/74	1. Diploneis sp.	2,701
	2. Centric diatoms	526
	3. Oocystis sp.	301
	4. Chroomonas sp.	188
	5. Chlamydomonas sp.	113
	Other genera	901
	Total	4,810

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/12/74	1	7.4
	2	6.1
	3	11.5
	4	17.3
05/21/74	1	18.4
	2	11.4
	3	14.0
	4	6.6
08/14/74	1	31.0
	2	27.5
	3	20.8
	4	4.4
11/05/74	1	22.3
	2	11.7
	3	23.0
	4	22.9

G. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.035	0.091	3.3
0.050 P	0.086	0.091	2.4
0.050 P + 1.0 N	0.086	1.091	16.2
1.0 N	0.035	1.091	9.5

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity

of Lake Corpus Christi was moderately high at the time the sample was collected (03/12/74). Also, a significant increase in yield resulted when only nitrogen was added but not when phosphorus alone was added. Based on these results, nitrogen limitation is indicated at that time.

The lake data indicate nitrogen limitation at all sampling times. The mean inorganic nitrogen to orthophosphorus ratios were 4 to 1 or less, and nitrogen limitation would be expected.

Nitrogen limitation, as indicated by the algal assay or by in-lake nitrogen to phosphorus ratios, does not necessarily mean that the trophic condition of the lake can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point or non-point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff month of May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads at station A-2, in kg/km²/year, and multiplying by the ZZ area in km².

The operator of the George West wastewater treatment plant provided monthly effluent samples and corresponding flow data. The operators of the wastewater treatment plants of Three Rivers and Mathis did not participate. Nutrient loads from these sources were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m³/capita/day.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
George West*	2,000	act. sludge	480.0	Timon Creek
Three Rivers**	1,725	ext. aer.	652.9	Frio River
Mathis**	4,100	tr. filter + pond	1,651.9	Unnamed Creek to Lake Corpus Christi

2. Known industrial - None

* Treatment plant questionnaire.
** Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Nueces River	195,250	91.7
b. Minor tributaries & immediate drainage (non-point load) -	7,455	3.5
c. Known municipal STP's -		
George West	1,895	0.9
Three Rivers	1,955	0.9
Mathis	4,650	2.2
d. Septic tanks* -	200	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	1,550	0.7
Total	212,945	100.0

2. Outputs -

Lake outlet - Alice Aqueduct	365
Nueces River	84,625

3. Net annual P accumulation - 127,955 kg.

* Estimate based on 712 lakeshore dwellings: see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Nueces River	1,472,295	89.2
b. Minor tributaries & immediate drainage (non-point load) -	52,195	3.2
c. Known municipal STP's -		
George West	1,300	0.1
Three Rivers	5,865	0.4
Mathis	13,945	0.8
d. Septic tanks* -	7,590	0.5
e. Known industrial - None	-	-
f. Direct precipitation** -	95,685	5.8
Total	1,648,875	100.0

2. Outputs -

Lake outlet -	Alice Aqueduct	2,605
	Nueces River	608,810
	Total	611,415

3. Net annual N accumulation - 1,037,460 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Nueces River	5	35

* Estimate based on 772 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	2.40	1.44	16.6	11.7

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake Corpus Christi:

"Dangerous" (eutrophic loading)	0.58
"Permissible" (oligotrophic loading)	0.29

V. LITERATURE REVIEWED

Anonymous, 1971. Inventory of municipal waste facilities. EPA Pub. OWP-1, vol. 6. Wash., DC.

Latchford, John B., Jr., 1974. Personal communication (lake morphometry). TX Water Qual. Bd., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RECREATION

LAKE CODE	LAKE NAME	[illegible] TOTAL #	[illegible] INCL %	[illegible] ACRES	[illegible] (MILES	[illegible] AVG	[illegible] 2035 [illegible] #
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	PALESTINE LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	S [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	E [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

LAKE CODE	LAKE NAME	[illegible] TOTAL *	[illegible] INCH * %	[illegible] MEAN SEC	[illegible] CYLIND	[illegible] MEAN SEC	[illegible] CESS [illegible] *	[illegible] NO
[illegible]	[illegible] LAKE	95 (39)	5 (2)	103 (55)	128 (69)	20 (14)	4 (2)	[illegible]
[illegible]	[illegible] LAKE	75 (30)	7 (29)	62 (33)	47 (18)	17 (8)	42 (34)	240
[illegible]	[illegible] RESERVOIR	62 (25)	29 (10)	47 (27)	68 (26)	17 (8)	64 (32)	289
[illegible]	[illegible] LAKE	5 (2)	42 (20)	59 (69)	1 (0)	48 (17)	5 (2)	179
[illegible]	[illegible] LAKE	69 (25)	78 (29)	29 (11)	87 (33)	58 (22)	94 (35)	396
[illegible]	LAKE [illegible]	47 (19)	21 (7)	74 (29)	63 (24)	17 (8)	29 (14)	251
[illegible]	CADDO LAKE	29 (23)	91 (23)	42 (16)	32 (12)	76 (29)	38 (18)	247
[illegible]	CALAVERAS LAKE	45 (17)	102 (38)	47 (18)	11 (4)	67 (25)	92 (34)	384
[illegible]	CANYON RESERVOIR	99 (37)	9 (3)	95 (36)	97 (37)	49 (17)	97 (37)	446
[illegible]	LAKE CHAMBERS CITY	39 (14)	76 (28)	25 (10)	42 (16)	88 (33)	39 (14)	318
[illegible]	CORPUS CHRISTI LAKE	8 (3)	47 (18)	18 (7)	13 (5)	61 (23)	0 (0)	155
[illegible]	DENISON LAKE	69 (26)	63 (30)	32 (12)	29 (11)	97 (37)	63 (21)	372
[illegible]	EAGLE [illegible] LAKE	71 (27)	91 (33)	36 (13)	74 (28)	79 (30)	76 (28)	426
[illegible]	FT PHANTOM HILL LAKE	24 (9)	66 (25)	21 (8)	74 (28)	95 (36)	19 (9)	299
[illegible]	GARZA LITTLE ELM RESERVO	36 (13)	17 (5)	16 (6)	36 (13)	55 (21)	21 (7)	173
[illegible]	HOOP LAKE	78 (29)	61 (23)	55 (21)	55 (21)	84 (32)	92 (34)	423
[illegible]	HOUSTON LAKE	19 (9)	36 (9)	3 (0)	24 (9)	72 (27)	11 (4)	139
[illegible]	LAKE OF THE PINES	54 (20)	79 (25)	66 (25)	39 (15)	17 (8)	46 (17)	248
[illegible]	LAVON RESERVOIR	21 (8)	29 (11)	3 (1)	84 (32)	100 (38)	21 (7)	258
[illegible]	LIVINGSTON LAKE	3 (1)	3 (1)	39 (15)	26 (10)	17 (8)	3 (1)	91
[illegible]	LYNDON B JOHNSON LAKE	39 (14)	11 (4)	53 (20)	66 (25)	39 (14)	38 (18)	236
[illegible]	MEDINA LAKE	89 (33)	8 (3)	89 (34)	37 (14)	17 (8)	108 (38)	342
[illegible]	LAKE [illegible]	62 (23)	91 (33)	71 (27)	45 (18)	38 (14)	63 (23)	441
[illegible]	PALESTINE LAKE	54 (20)	32 (12)	63 (24)	53 (20)	47 (17)	51 (19)	362
[illegible]	PECOS [illegible] RESERVOIR	74 (28)	91 (33)	44 (17)	38 (20)	17 (8)	63 (23)	397
[illegible]	SAN ANGELO RESERVOIR	13 (5)	45 (17)	8 (3)	8 (0)	58 (33)	46 (17)	201
[illegible]	SAN ANTONIO RESERVOIR	59 (22)	39 (15)	69 (26)	76 (29)	17 (8)	63 (23)	322
[illegible]	E V SPENCE RESERVOIR	58 (19)	63 (32)	45 (17)	58 (19)	17 (8)	79 (28)	321

[illegible] OF LAKES WITH [illegible] KILLS [illegible] NUMBER OF LAKES WITH [illegible] KILLED

LAKE CODE	LAKE NAME	[illegible] TOTAL #	[illegible] TROUT %	[illegible] [illegible] ACC	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO.
29	[illegible]	LYNDON B. JOHNSON LAKE	239
30	[illegible]	TEXOMA LAKE	237
31	[illegible]	SOMERVILLE LAKE	206
32	[illegible]	SAN ANGELO RESERVOIR	200
33	[illegible]	TEXARKANA LAKE	176
34	[illegible]	BAYOU LITTLE BLUE RESERVOIR	173
35	[illegible]	TRINIDAD	169
36	[illegible]	BROWNS LAKE	159
37	[illegible]	CORPUS CRISTI LAKE	155
38	[illegible]	HOUSTON LAKE	139
39	[illegible]	LIVINGSTON LAKE	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

LAKE CASE [illegible] CORPUS CHRISTI LAKE

TOTAL DRAINAGE AREA OF LAKE/RES [illegible]

SUBAREA	SUBAREA DRAINAGE AREA (SQ MI)	JAN	FEB	MAR	APR	MAY	NORMALIZED FLOWS(CMS) JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
[illegible]	[illegible]	10.42	10.49	9.61	12.48	[illegible]	20.11	21.75	24.72	63.71	48.19	11.23	9.61	24.47
[illegible]	[illegible]	9.29	11.34	8.78	16.49	[illegible]	[illegible]	38.82	36.42	53.52	42.14	11.49	8.23	24.47
[illegible]	6.2	8.493	8.385	8.189	8.136	8.138	8.841	8.884	8.849	8.896	8.879	8.841	8.843	8.301
[illegible]	1574.9	8.34	8.42	8.34	8.45	1.59	1.76	1.13	8.62	2.04	1.41	8.48	8.26	8.43

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = [illegible]
SUM OF SUB-DRAINAGE AREAS = [illegible]

TOTAL FLOW IN = 385.74
TOTAL FLOW OUT = 293.86

NOTE [illegible] NO DRAINAGE AREA FOR [illegible]

[illegible] MONTHLY FLOWS AND WEEKLY FLOWS(CMS)

SUBAREA	MONTH	YEAR	MONTH FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
[illegible]	9	74	62.388	1	138.594				
	10	74	6.226	4	4.225				
	11	74	6.218	11	3.598				
	12	74	5.469	18	3.728				
	1	75	4.685	24	2.775				
	2	75	6.196	35	18.619				
	3	75	3.683	78	2.577				
	4	75	3.688	12	2.442				
	5	75	6.854	3	3.256	29	3.171		
	6	75	58.417	21	22.493				
	7	75	6.598	17	10.769				
	8	75	6.683	28	4.313				
[illegible]	9	74	6.881	8	148.387				
	10	74	5.154	4	5.629				
	11	74	11.447	1	9.231				
	12	74	5.728	8	6.768				
	1	75	5.359	18	5.852				
	2	75	12.866	15	11.446				
	3	75	6.444	23	6.878				
	4	75	5.537	12	3.882				
	5	75	58.896	3	4.955	29	18.487		
	6	75	61.154	21	51.825				
	7	75	36.862	17	24.817				
	8	75	6.738	28	5.324				

APPENDIX D

PHYSICAL and CHEMICAL DATA

APPENDIX I

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
74/04/04	18	58		4.156	1.388	4.838	0.140	0.418
74/10/04	12	45		1.441	0.488	0.628	0.096	0.146
74/10/01	11	15		2.241	0.781	0.825	0.058	0.116
74/12/04	13	48		1.769	0.585	0.836	0.060	0.096
75/01/19	18	45		2.861	0.681	0.846	0.112	0.056
75/02/15	12	53		1.536	0.481	0.842	0.064	0.096
75/03/24	18	09		3.868	0.686	9.625	0.635	0.086
75/04/12	15	08		4.886	0.384	0.825	0.855	0.045
75/05/01	11	35		1.468	0.486	0.845	0.065	0.136
75/05/24	18	45		1.458	1.586	0.178	0.144	0.296
75/06/21	15	18		2.228	1.858	0.845	0.279	0.486
75/07/17	14	38		1.158	0.758	0.822	0.165	0.236
75/08/25	19	08		0.328	0.488	0.825	0.028	0.128

[illegible]

[illegible]

[illegible]
27 [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE FROM	TIME OF DAY	DEPTH FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]
[illegible]

[illegible]